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ADAPTIVE ARRAYS IN PACKET RADIO NETWORKS

FINAL REPORT

R. T. COMPTON, JR.

JULY 1991

U. S. ARMY RESEARCH OFFICE

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ELECTROSCIENCE LABORATORY

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   (c) R. L. Hamilton and B. S. Leung, "Product Form Solutions for a Tandem Packet-Radio Queueing System," submitted to *IEEE Transactions on Automatic Control*, January 1990.
   (d) J. Ward and R. T. Compton, Jr., ":Improving the Performance of a Slotted ALOHA Packet Radio Network with an Adaptive Array," to appear in *IEEE Transactions on Communications.*
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STATEMENT OF THE PROBLEM

This research considered the use of adaptive antennas in packet radio networks (PRNs). By using an adaptive array at a packet radio terminal, the receiving pattern of a terminal can change in response to each received packet. For example, in a slotted system, a terminal with an adaptive array can receive one or more packets correctly in a slot even when the slot contains colliding packets, because the array automatically nulls the colliding packets.

Under this contract, we have first studied the performance of a single packet radio terminal using a multibeam adaptive array. The throughput-delay performance of the packet terminal has been evaluated for both slotted and unslotted channels. In addition, we have also studied the throughput-delay performance of a small slotted network that uses a single-beam adaptive array at each terminal.

SUMMARY OF THE MOST IMPORTANT RESULTS

Previous work [1] had shown that the performance of a packet radio terminal could be substantially improved by using a single-beam adaptive array at the terminal. The improvement is similar to that of Carrier Sense Multiple Access (CSMA) [2]. However, an adaptive array has the advantage over CSMA that, unlike CSMA, it does not require all terminals in the network to be able to hear one another.

Under this contract, we first studied the throughput-delay performance of a single packet radio receiver that uses a *multibeam* adaptive array. A multibeam adaptive array is one that forms several beams (or patterns) simultaneously from the same array elements. We have shown that with a multibeam adaptive array, a packet radio terminal can achieve average throughputs of 3 or 4 packets per packet width. This result can be achieved in either slotted or unslotted systems. (The method of acquiring packet timing and adapting the array pattern is, however, different for slotted and unslotted systems.)

Second, under this contract we have also studied what happens when adaptive arrays are used in multihop (PRNs). As part of this work, we have developed some tools needed for predicting the performance of multihop PRNs with adaptive arrays. Specifically, an approximate algorithm has been developed for determining the average packet delay in slotted ALOHA PRNs with adaptive arrays. Comparisons of the

results predicted by this algorithm with those obtained from simulations indicate that this algorithm is accurate for most traffic levels.

Our results for network performance with adaptive arrays show that adaptive arrays dramatically increase the throughput-delay performance of a slotted ALOHA PRN. For example, we have shown that the addition of a simple 3-element adaptive array to each node in a 10-node network dramatically improves the average delay. Moreover, most of the improvement is obtained by using an array with only one null. The improvement does depend, of course, on the network traffic. Performance improvements due to the adaptive arrays occur mainly at medium to high traffic levels. (At low traffic levels, there are so few collisions that adaptive arrays have little effect. But at higher traffic levels, adaptive arrays significantly reduce the frequency of collisions and hence reduce delays.)

[1] M. Azizoglu, R. T. Compton, Jr., F. D. Garber, G. M. Huffman and H. C. Yu, "Adaptive Arrays in Satellite Packet Radio Communication Systems," Technical Report 718163-2, August 1987, The ElectroScience Laboratory, Department of Electrical Engineering, Ohio State University, Columbus, OH 43212; prepared for the National Aeronautics and Space Administration, Lewis Research Center, 21000 Brook Park Rd., Cleveland, OH 44135 under Contract No. NAS3-24888.

[2] L. Kleinrock and F. A. Tobagi, "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access and Their Throughput-Delay Characteristics," *IEEE Transactions on Communications*, Vol. COM-23, No. 12 (December 1975), pp. 1400-1416.